A 15-year implementation plan

Clean, Safe Creeks & Natural Flood Protection

The People Behind your

Impaired Water Bodies Improvement Program

Executive Summary Report:

Guadalupe Watershed Mercury Study

January 20, 2005

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DEFINITIONS OF TERMS USED IN THIS DOCUMENT

Total Mercury:	The measured amount of all forms of mercury in a sample of sediment or water sample; this includes methyl mercury, dissolved mercury, and elemental mercury. If a sample result is reported as "mercury concentration," total mercury is assumed.
Dissolved Mercury:	The measured amount of mercury remaining in a water sample that has been filtered to remove suspended sediment.
Methyl Mercury:	The most bioavailable and most toxic form of mercury. Methyl mercury is formed when anaerobic sulfate-reducing bacteria methylate inorganic mercury.
Inorganic Mercury:	Inorganic mercury compounds are formed when mercury combines with elements other than carbon, such as chlorine, sulfur, or oxygen. Elemental mercury is a form of inorganic mercury.
Load Allocation:	The mass of mercury that can be released from a specific source on a daily or annual basis.
Load Reduction:	The mass of mercury needed to be removed from a source to meet the load allocation for that source.
TMDL:	A Total Maximum Daily Load (TMDL) is a plan for restoring water bodies that do not support beneficial uses because of impairment caused by a pollutant. A TMDL identifies and quantifies sources of the pollutant causing impairment, calculates the maximum daily load of the pollutant that a water body can receive and still support beneficial uses, and assigns load allocations for each source so that this daily (or annual) load is achieved.
mg/kg:	Milligrams of measured substance per kilogram of sample weight (also expressed as parts per million). A milligram is one-thousandth of a gram and one-millionth of a kilogram. The measure is equivalent to micrograms per gram (ug/g). Ex: The concentration of mercury in a fish sample expressed as milligrams of mercury per kilogram of fish or micrograms of mercury per gram of fish.
ug/l:	Micrograms per liter (also expressed as parts per billion). Ex: The concentration of mercury in water expressed as micrograms of mercury per liter of water.
ng/l:	Nanograms per liter (also expressed as parts per trillion). A nanogram is one-billionth of a gram, i.e. 10^{-9}g.
Dry weight:	If a sediment sample is treated to remove moisture prior to analysis, the analytical results are expressed as dry weight. For example: 20mg/kg total mercury, dry weight.

Wet weight: If a sediment sample is analyzed with the natural water content as received, the results are said to be "wet-weight" but wet-weight is not always stated. Unless "dry-weight" is stated, wet-weight must be presumed. Weight-wet sediment samples understate mg/kg mercury concentration by the percentage of moisture content.

Hypolimnion: The cold lower layer of a stratified lake, under the epilimnion and beginning just below the thermocline. This layer is not directly affected by surface events.

Epilimnion: The warm upper layer of a stratified lake, beginning just above the thermocline. This layer is directly affected by surface events.

Thermocline: The distinct interface between surface waters and cooler, deeper waters; the region between the warm upper layer (epilimnion) and the lower cold layer (hypolimnion) of the lake, where temperature declines abruptly (1C° or more per meter) with increasing depth.

BACKGROUND

In 1998, the San Francisco Bay Regional Water Quality Control Board (Regional Board) reported to the U.S. Environmental Protection Agency (EPA) that certain water bodies in the Guadalupe River Watershed did not support designated beneficial uses, in part, due to the presence of mercury in fish tissue that exceeded applicable criteria. In 1999, the Regional Board approached the recently formed Santa Clara Basin Watershed Management Initiative (WMI) to serve as the public stakeholder group for development of a plan for reducing mercury in fish tissue and thereby restore the impaired beneficial uses with regard to this specific pollutant. The plan is termed a Total Maximum Daily Load (TMDL), and the Regional Board is required by the Clean Water Act to develop TMDLs for water bodies that do not support beneficial uses. A TMDL identifies and quantifies sources of the pollutant causing impairment, calculates the maximum daily load of the pollutant that a water body can receive and still support beneficial uses, and assigns load allocations for each source so that this daily load is achieved.

Also in 1999, the Regional Board formed a Mercury Council to develop a TMDL for mercury in San Francisco Bay. The Regional Board released a draft TMDL Project Report in June 2000 that called for a 98% reduction of the load of mercury from the Guadalupe River to the Bay, and a 50% reduction of the load of mercury in urban runoff to the Bay. This TMDL, including these load allocations, was eventually adopted by the Regional Board in September 2004. The timeline in the TMDL requires reducing the load of mercury from the Guadalupe River by and annual average of 46 kilograms per year by the end of the first ten years of implementation, and by the full annual average of 92 kilograms per year by the end of the next ten years. This timeline also applies to the urban runoff load reduction.

In response to the Regional Board request, the WMI formed a Work Group that was co-chaired by a representative of the Regional Board and by a representative of the Santa Clara Valley Water District (District). In 2000, the Work Group developed a Work Plan for development of the TMDL that was approved by the Core Group of the WMI. In September 2002, the District Board approved a staff request to execute a consultant agreement for the study ($884,583), and directed staff to negotiate a Memorandum of Understanding (MOU) with the Regional Board.

In March 2003, the District Board and the Regional Board adopted a MOU that established roles and responsibilities for District and Regional Board staff, committed the District and Regional Board to use the WMI as the public forum for development of the TMDL, and confirms that District current, planned and future efforts to reduce mercury in the environment will be accounted for in both the Guadalupe River Watershed TMDL and the San Francisco Bay TMDL. The intent is to ensure that Implementation of the Guadalupe River Watershed TMDL will also satisfy implementation requirements for the San Francisco Bay TMDL. In the San Francisco Bay TMDL adopted by the Regional Board, credit for past activities conducted by the District is retroactive to 1998.

The District's contribution to the TMDL, as defined in the MOU, is to provide sufficient data and interpretation so that the TMDL is based on sound science. This will ensure that allocation of loads among source owners and source control measures will achieve the greatest benefit. In addition, the MOU ensures the provision and latitude to the District for projects that generate benefits greater than just reduction of mercury loading, such as restoration of habitat, thereby allowing the District to meet multiple objectives, including other environmental obligations.

Methyl mercury is the toxic form of mercury that enters the food web and bioaccumulates into higher trophic levels. The process of mercury methylation occurs primarily at the sediment-water interface under a particular set of environmental conditions. Methyl mercury produced from microbial processes is soluble and environmentally mobile, quickly entering aquatic food webs. Almost all mercury that is bioaccumulated is in the methylated form, primarily as a result of the consumption of prey containing methyl mercury. Methyl mercury accumulates in carnivorous fish to levels of 100,000 to 1,000,000 times those found in ambient water.

The focus of the District's study of mercury in the watershed was to identify where methyl mercury is being produced in the watershed, the sources of mercury to those areas, and if there are any potential controls for reducing methyl mercury production. In contrast to the San Francisco Bay Mercury TMDL, which focuses only on inorganic mercury associated with suspended sediment, the Guadalupe River Watershed TMDL will recognize the importance of methyl mercury in addition to inorganic mercury in sediment. This will result in an implementation plan that prioritizes actions to reduce methyl mercury production by:

- reducing loads of mercury in sediment to areas where methyl mercury is produced; and,
- controlling factors associated with increased methyl mercury production

EXECUTIVE SUMMARY

The Santa Clara Valley Water District conducted a study of mercury in the Guadalupe River Watershed between March 2003 and December 2004. The purpose of this study was to develop the data to support development of a Total Maximum Daily Load (TMDL) for Mercury in this watershed based on sound science. The District conducted this study under a Memorandum of Understanding with the San Francisco Bay Regional Water Quality Control Board (Regional Board) in part, to ensure that a single Implementation Plan would be developed to address mercury in the watershed and in San Francisco Bay.

The TMDL for the watershed is required because fish tissue concentrations of mercury in fish collected from various water bodies in the watershed exceed applicable criteria for human consumption. The study was conducted because of the lack of information regarding mercury sources, fate and transport, and lack of understanding of the linkage between mercury in sediment and mercury in fish tissue.

The study included four main bodies of work:

- An initial review of all available data related to mercury in the watershed.
- A reconnaissance-level survey of the watershed to identify sources of mercury, collect soil and water samples for mercury analyses, and develop dry season load estimates of mercury and methyl mercury.
- Development of a conceptual model of mercury impact and transport in the watershed.
- Collection of soil, water and fish data to address data gaps identified in the conceptual model, test assumptions contained in the model, and develop wet season load estimates of mercury and methyl mercury.

The key findings of the study are:

- Mercury loads from the mining district to the reservoirs and to the creeks downstream of the reservoirs are significant and are about 10 times the loads measured in "background" areas away from the sites of mercury mining.
- The largest source of mercury in the watershed is in-stream bank and bed deposits of sediment and mine wastes, primarily in Alamitos and Guadalupe Creeks, and most of this in-stream load of total mercury is mobilized during storm flows.
- Most of the in-stream bed load of mercury is attached to sediment from Alamitos and Guadalupe Creeks, and is trapped in Lake Almaden and in the impound area (recharge basin) behind the Alamitos Drop Structure, respectively.
- Water transfers through the Almaden-Calero Canal is a significant source of mercury to Calero Reservoir.
- Loads of total mercury in the water column into Almaden, Calero and Guadalupe Reservoirs are greater than loads exiting the reservoirs to downstream creeks.
- Loads of total mercury in the water column into the Alamitos Drop Structure impound area (recharge basin) and into Lake Almaden are greater than the load exiting the Drop Structure to Guadalupe River.
- The load of total mercury in the water column exiting Guadalupe River to the Bay is greater than the collective load into the River from (a) mining district tributaries; (b) non-mining district tributaries, and (c) urban runoff.
- Mercury concentrations in all adult fish collected from all reservoirs exceed the applicable criterion for human consumption. Nearly all mercury in fish occurs as methyl mercury.

- Deposition of mercury from the atmosphere results in mercury concentrations in adult fish that exceed the applicable criterion for human consumption.
- Mercury concentrations in adult and Age-1 fish from Guadalupe, Almaden and Calero Reservoirs and Lake Almaden are two to ten times higher than in adult and Age-1 fish collected from reservoirs affected only by atmospheric deposition and local un-mined geologic sources of mercury (Lexington, Stevens Creek, and Anderson Reservoirs).
- Mercury concentrations in Age-1 fish collected below the reservoirs from streams impacted by mercury from the mining district (Alamitos Creek, Guadalupe Creek, Guadalupe River) decrease with distance downstream (from 0.39 to 0.08 mg/kg), and are three to thirteen times higher than mercury in fish (0.03 mg/kg) collected from a stream (Los Gatos Creek) not affected by mercury from the mining district.
- Almaden and Guadalupe Reservoirs produce significant amounts of methyl mercury, and this is associated with seasonal depletion of oxygen in the hypolimnion of the reservoirs.
- Methyl mercury concentrations in the water column decrease with distance downstream of the reservoirs during the dry season.
- Mercury concentrations in fish are correlated with methyl mercury concentrations in the water column.

The key implications of the study are:

- Mercury loads need to be reduced, particularly those loads that enter sites where methyl mercury production is significant, including the reservoirs, Lake Almaden, and the flooded area behind the Alamitos Drop Structure.
- Methyl mercury production needs to be reduced at sites where its rate of production is significant, including the reservoirs, Lake Almaden, and the flooded area behind the Alamitos Drop Structure.

The TMDL for mercury in San Francisco Bay assigned load allocations based only on total mercury concentrations in the water column, and included an allocation for Guadalupe River. This allocation, expressed as 200ng/g total mercury in suspended sediment in the water column, will be included in the TMDL for mercury in the Guadalupe River. The Bay TMDL established a correlation between mercury concentrations in sediment and methyl mercury concentrations in fish from the Bay. The target concentrations for methyl mercury in fish from the Bay were used to establish the load allocations for the sources of total mercury in the suspended sediment in the water column to the Bay.

In the Guadalupe River Watershed, a meaningful correlation between mercury in sediment samples and methyl mercury in fish samples was not observed. Nor was there a correlation between total mercury in samples from the water column and methyl mercury in fish samples. However, a correlation between methyl mercury in samples from the water column and methyl mercury in fish samples was observed. This will result in load allocations in the Guadalupe River Watershed TMDL expressed in terms of total mercury (for the load to the Bay) and methyl mercury (for loads within the watershed) in the water column.

The Guadalupe River Watershed TMDL will contain numeric targets for mercury in fish, mercury in water and sediment, and methyl mercury in water that are protective of humans and wildlife exposed to mercury via consumption of fish. The load allocations in the TMDL will require reductions for the following types of loads of mercury in the water column:

- total mercury loads in the water column to the reservoirs from tributaries draining the mining district;

- total and methyl mercury loads in the water column from the reservoirs to downstream creeks;
- total mercury loads in the water column to downstream creeks from tributaries draining the mining district;
- total mercury loads in the water column to Lake Almaden and to the Alamitos Drop Structure from in-stream bed and bank erosion;
- total and methyl mercury loads in the water column from Lake Almaden and the Alamitos Drop Structure to the main stem of the Guadalupe River;
- total mercury loads in the water column to Guadalupe River from urban runoff equal to the Bay TMDL; and,
- total mercury load in the water column from Guadalupe River to the Bay equal to the Bay TMDL.

From the perspective of the Regional Board, responsibility for meeting load allocations will rest with current property owners, and will be enforced by the Regional Board under their existing authorities derived from the Porter-Cologne Water Quality Act and the Clean Water Act. The Bay TMDL provides twenty years to achieve the load reductions from all sources, and estimates that full recovery of the Bay may take another century beyond that, due to the mercury already existing in the Bay sediments. The Guadalupe River Watershed TMDL will include a similar reasonable time period for achieving load reductions, but it is anticipated that the time required for at least partial restoration of the beneficial uses (e.g. relaxation from an outright ban of consumption to a restricted consumption of fish) will be much shorter. However, the importance of atmospheric deposition as a contributor to mercury in fish tissue was demonstrated by this study. Achieving non-restricted consumption of fish from all water bodies in the watershed (and possibly the Bay) is unlikely to occur until global sources of atmospheric mercury are reduced.

The recommended strategy for the District is as follows:

- Quantify mercury removal and estimated load reductions already achieved by the construction of the Lower and Downtown Guadalupe River Flood Protection Projects, the Guadalupe Creek Restoration Project, and annual stream maintenance activities already completed since 1998. This will determine the credit available to the District to apply toward the Bay TMDL load reduction requirement.
- Incorporate and quantify mercury removal and load reductions into the Upper Guadalupe River Flood Protection Project.
- Recognize mercury removal benefits of ongoing and planned routine stream maintenance programs in the watershed.
- Incorporate mercury as a criterion for prioritizing erosion control activities.
- Evaluate the potential of using Pond A8 as a repository for sediment mobilized under high flow conditions as part of a multi-objective approach to providing flood protection and restoration of habitat.
- Establish an annual goal for mercury removal projects as a percentage of all stream maintenance activities in the watershed as part of a multi-objective approach to meeting goals of stream restoration, habitat enhancement, property protection, and mercury load reduction.
- Develop and implement a routine maintenance program to remove sediment from behind the Alamitos Drop Structure, at the inlet to Lake Almaden, and at other sediment accumulation sites.
- Investigate and implement methods to reduce methyl mercury production in reservoirs, Lake Almaden, and behind the Alamitos Drop Structure as part of a multi-objective

approach to meeting goals of improved fisheries, improved water quality, reduced water treatment costs, and methyl mercury reduction in water and fish.

- Develop a long term plan for restoration of the Lake Almaden-Alamitos Drop Structure area, including sediment removal, reducing methyl mercury production, improving fish passage, and enhancing habitat and recreational opportunities.
- Evaluate the potential of retiring Almaden Reservoir and/or Guadalupe Reservoir as part of a long-term approach to restoration of Alamitos Creek and Guadalupe Creek.
- Develop staff expertise in monitoring and sampling water, sediment and biota to address mercury and other existing or potential pollutants.

This strategy addresses the Cleaner, Greener, Leaner goals of the District:

- Cleaner:
  - Improved water quality for fisheries in the reservoirs and downstream creeks

- Greener:
  - Restored and enhanced environment in the reservoirs and downstream creeks
  - Improved fish habitat and related food cycle and wildlife habitat in the reservoirs and downstream creeks
  - Improved recreational opportunities

- Leaner:
  - Utilization of existing projects and other proposed multi-objective projects and activities to simultaneously address stream stewardship, flood protection, and water supply interests
  - Proactive action to minimize regulatory administrative burden

SUMMARY OF THE STUDY RESULTS

The District championed a comprehensive approach to conducting the study, utilizing the public stakeholder group to provide review and comment on draft work products, and to reach consensus on the direction of the study as it progressed. A Technical Review Committee was formed to provide independent, third-party expert review of the Draft Conceptual Model and the Draft Data Collection Plan. The work products produced by the consultant are listed below and are available on the District's web site:

- Preliminary Problem Statement
- Synoptic Survey Plan and Report
- Draft Final Conceptual Model Report
- Data Collection Plan and Report

Preliminary Problem Statement

The initial work product of the study was a Preliminary Problem Statement Report that summarized existing data and information in the watershed. The report provided:

- Background information on the watershed setting for the TMDL by summarizing important water quality, pollutant discharge, land-use, and resource protection issues.

- A description of the water quality impairment which necessitated the TMDL development that includes the identification of the water body segments for which the TMDL is being developed and the potentially applicable water quality standards for mercury.

- A description of the current understanding of processes and factors controlling mercury in the watershed, emphasizing that a mechanistic understanding of the fate, transport and bioaccumulation processes of mercury in the watershed, based on locally collected data, is essential to the development of a successful TMDL.

Synoptic Survey

The Synoptic Survey, conducted during the dry season (Summer 2003), was a field reconnaissance of the watershed to visually identify sites of significant erosion, mine waste deposits, and creek vegetation, and also included collection of fish from Guadalupe Reservoir and sediment and water samples from various locations in the watershed. The Synoptic Survey was designed to meet two primary objectives:

- Complete a visual inspection to provide a general view of mercury contamination in the watershed. The survey had wide spatial coverage surveys for wetland vegetation (Figure 1), sediment erosion and accumulation sites, and to identify areas of existing deposits of mercury mine waste (Figure 2).

- The second objective was sampling to produce an early indication of key locations where transformation of solid phase mercury to bioavailable mercury is and is not occurring in the surface waters of the Guadalupe Watershed that drain to the tributaries, outfalls, Guadalupe River, and the Bay. Samples for chemical analyses were collected at 24 different locations in the creeks and reservoirs, using a consistent set of sampling and analytical methods.

Figure 1 Example of wetland vegetation along portions of Alamitos Creek

Figure 2 Example of undercut bank of cemented mine waste on Alamitos Creek

Draft Final Conceptual Model

The Preliminary Problem Statement Report and the Synoptic Survey Report provided sufficient information to develop a Draft Final Conceptual Model for the impact and transport of mercury in the watershed. The Draft Final Conceptual Model Report used data from the two reports to identify important sites of methyl mercury production during the dry season, to estimate mercury loads from atmospheric deposition, to estimate loads in reservoir inlets and outlets, to estimate in-stream loads, and to estimate loads from the Guadalupe River to the Bay.

In the model, the system is divided into five groups of water bodies:

- Reservoirs
- Streams and creeks in the upper watershed (above Ross Creek) draining the historic mercury mine areas
- Creeks in the upper watershed draining areas not known to contain mines
- Guadalupe River downstream of Almaden Lake to St. Johns Street
- Guadalupe River from St. Johns Street to Alviso Slough

Overview of Conceptual Model

Most of the mercury remaining in the watershed seems to exist as relatively insoluble mercury sulfides in mine wastes that have accumulated in reservoir deposits and sediments, and in stream bottoms, banks and flood plains. Because of the strong association of mercury with solids, the movement of mercury in the watershed is closely tied to the transport of sediments. Sediment mercury concentrations in the creeks exhibit a significant and consistent decline with distance downstream of the mining area.

The conceptual model indicates the following:

- Wet season high flows deliver practically all of the total mercury transported in the watershed.

- The four major reservoirs, Lexington, Almaden, Guadalupe and Calero are sinks for total mercury; they all release less total mercury than they receive.

- Inputs of mercury derived from mine wastes are substantially greater than atmospheric deposition inputs for Guadalupe and Almaden Reservoirs, and for Alamitos and Guadalupe Creeks.

- Atmospheric deposition appears to account for a significant fraction of the mercury input to both Calero and Lexington Reservoirs.

Data Collection Plan and Report

The Data Collection Plan included seven elements, each of which was intended to address specific questions and hypotheses developed by the public stakeholder group. The data from Sampling Elements 1 through 4 resulted in the estimation of wet season loads of total, dissolved, and methyl mercury within the watershed and from Guadalupe River to the Bay. These data will be the core of the TMDL regarding loads and load allocations. The estimated loads for the wet season are shown on Figures 3 and 4. The sampling elements to develop these load estimates were as follows:

- Sampling Element 1 collected data to estimate the contribution of mercury in runoff from the tributaries to the reservoirs, providing estimates of the "background" mercury load (defined as the sum of atmospheric deposition and local un-mined geologic sources) and the relative increased load due to mercury in tributaries draining the mining district (identified as "mines" on Figure 3). Background loads of total mercury to Almaden, Calero and Guadalupe Reservoirs range from 13.9 to 27.5 grams per season. The background load to Lexington Reservoir is estimated to be 112 grams per season, comparatively larger due to its much larger watershed. Similarly, methyl mercury from the mining district sources is higher than background sources.

- Sampling Element 2 collected data to estimate the contribution of mercury in runoff from in-stream mobilization of bank and bed sediment in Alamitos, Guadalupe and Calero Creeks. The total mercury load appears to decrease in Guadalupe Creek with distance downstream of Guadalupe Reservoir, with about 61% of the load retained in the creek and behind the Alamitos Drop Structure. The total mercury load appears to increase significantly in Alamitos Creek between Almaden Reservoir and its confluence with Calero Creek (indicating in-stream mobilization of sediment as a source of mercury in the water column), with about 31% of the load retained in Alamitos Creek, Lake Almaden and behind the Alamitos Drop Structure. The total mercury load appears to decrease in Calero Creek with distance downstream of Calero Reservoir, with about 33% of the load retained in the creek. Methyl mercury loads behave similarly.

- Sampling Element 3 provided data to estimate the contribution of mercury in urban runoff. The data show that, for most urban drainages, the contribution of total and methyl mercury in urban runoff is about the same order of magnitude as the contribution from background sources.

- Sampling Element 4 provided data to determine what happens to the mercury as it reaches the main stem of the Guadalupe River and how much is discharged to the Bay. The estimated total mercury load to the Bay (9956.3 grams per season) is about 12 times higher than the estimated loads into the River from all sources (821.4 grams per season), indicating in-stream mobilization of sediment as a source of total mercury in the water column. The methyl mercury load to the Bay (26.7 grams per season) is over 3 times higher than the estimated loads into the River from all sources (7.4 grams per season).

Load estimates were calculated separately for the wet and dry season because of the dramatically different flow conditions in each season. For comparison, the daily load estimates of total mercury for the dry season, derived from the Synoptic Survey data, are shown on Figure 5. The dry season data indicate that:

- Total mercury entering the reservoirs from atmospheric deposition and (for Calero Reservoir) transfers from San Luis Reservoir, range from 0.011 grams per day (as shown or 1.3 grams per season) to 0.1 grams per day (12 grams per season). During the dry season, there is no significant flow from the mining areas upstream of the reservoirs.

- Total mercury exiting the two reservoirs (Almaden and Guadalupe Reservoirs) in the historic mining area is a significant source (0.11 grams and 0.27 grams per day, as shown, or 13.2 and 32.4 grams per season) and each is greater than the load from Calero Reservoir, which is in the non-mining area (0.03 grams per day, as shown, or 3.6 grams per season). The total mercury load from Lexington Reservoir, which is also in

the non-mining area, is estimated to be 0.73 grams per day (87.6 grams per season), due to its much larger volume of dry season releases.

The dry and wet season loads of total mercury exiting the reservoirs are compared below:

Almaden Reservoir
- Dry Season Load: 13.2 grams (to Alamitos Creek)
- Wet Season Load: 111.8 grams (to Alamitos Creek)
  190.2 grams (to Calero Reservoir)

Guadalupe Reservoir
- Dry Season Load: 32.4 grams (to Guadalupe Creek)
- Wet Season Load: 149.2 grams (to Guadalupe Creek)

Calero Reservoir
- Dry Season Load: 3.6 grams (to Calero Creek)
- Wet Season Load: 27.7 grams (to Calero Creek)

Lexington Reservoir
- Dry Season Load: 87.6 grams (to Los Gatos Creek)
- Wet Season Load: 141 grams (to Los Gatos Creek)

- Methyl mercury loads (not shown on Figure 5) exiting the two reservoirs in the historic mining areas (Almaden and Guadalupe Reservoirs) during the dry season are significant sources (7.6 grams and 14.2 grams per season) and are greater than the loads from Calero Reservoir (2.6 grams per season) and Lexington Reservoir (5.2 grams per season). The dry and wet season loads of methyl mercury exiting these reservoirs are compared below:

  Almaden Reservoir
  - Dry Season Load: 7.6 grams (to Alamitos Creek)
  - Wet Season Load: 0.8 grams (to Alamitos Creek)
    0.8 grams (to Calero Reservoir)

  Guadalupe Reservoir
  - Dry Season Load: 14.2 grams (to Guadalupe Creek)
  - Wet Season Load: 1.4 grams (to Guadalupe Creek)

  Calero Reservoir
  - Dry Season Load: 2.6 grams (to Calero Creek)
  - Wet Season Load: 0.3 grams (to Calero Creek)

  Lexington Reservoir
  - Dry Season Load: 5.2 grams (to Los Gatos Creek)
  - Wet Season Load: 0.9 grams (to Los Gatos Creek)

- In the dry season, total mercury concentrations increase with distance downstream of all of the reservoirs, but methyl mercury concentrations decrease with distance downstream of all reservoirs. This indicates that the amount of methyl mercury produced in the creeks is less than that produced in the reservoirs.

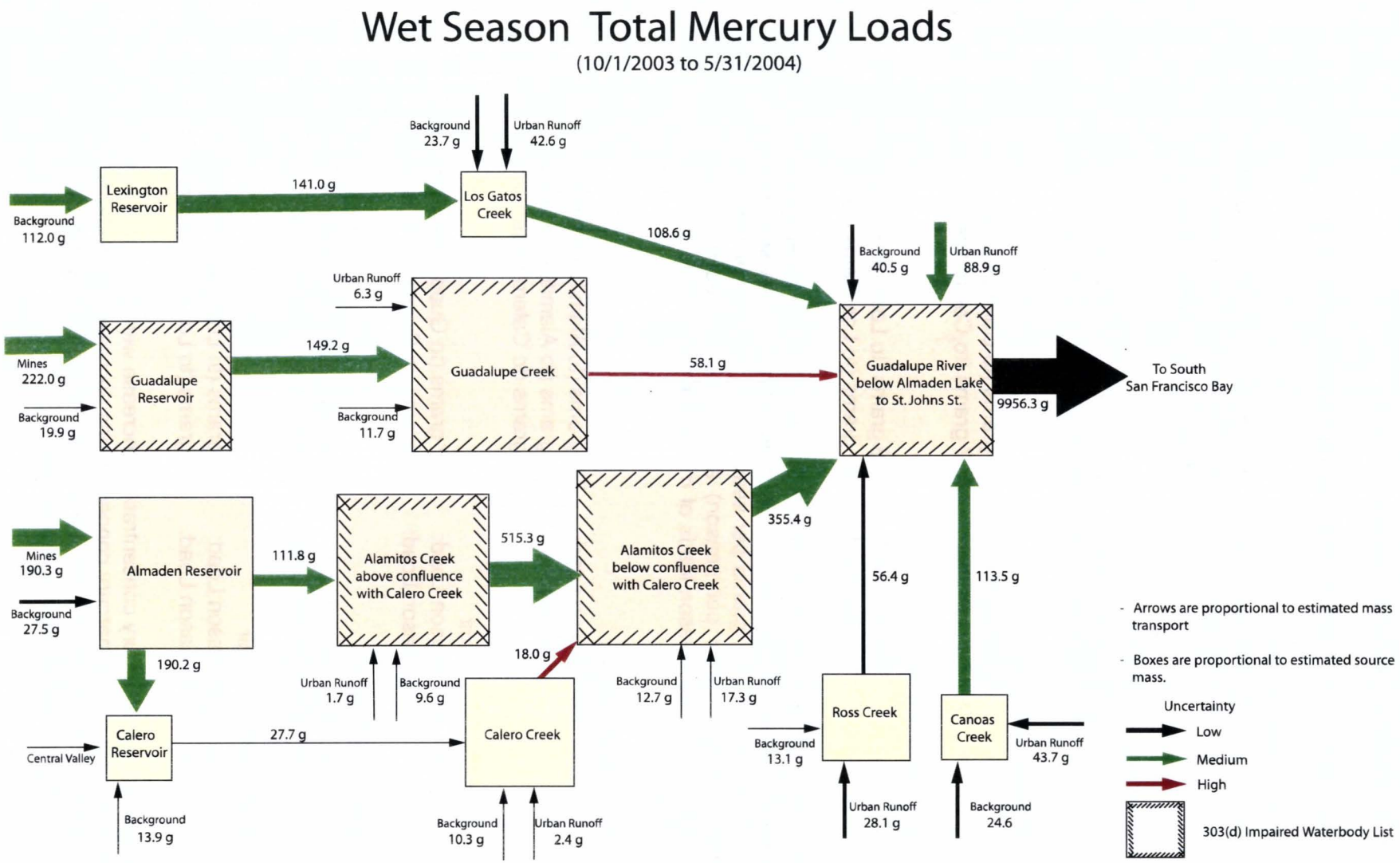


Figure 3: Graphical depiction of total mercury pathways through the Guadalupe River Watershed. All loads are in grams.

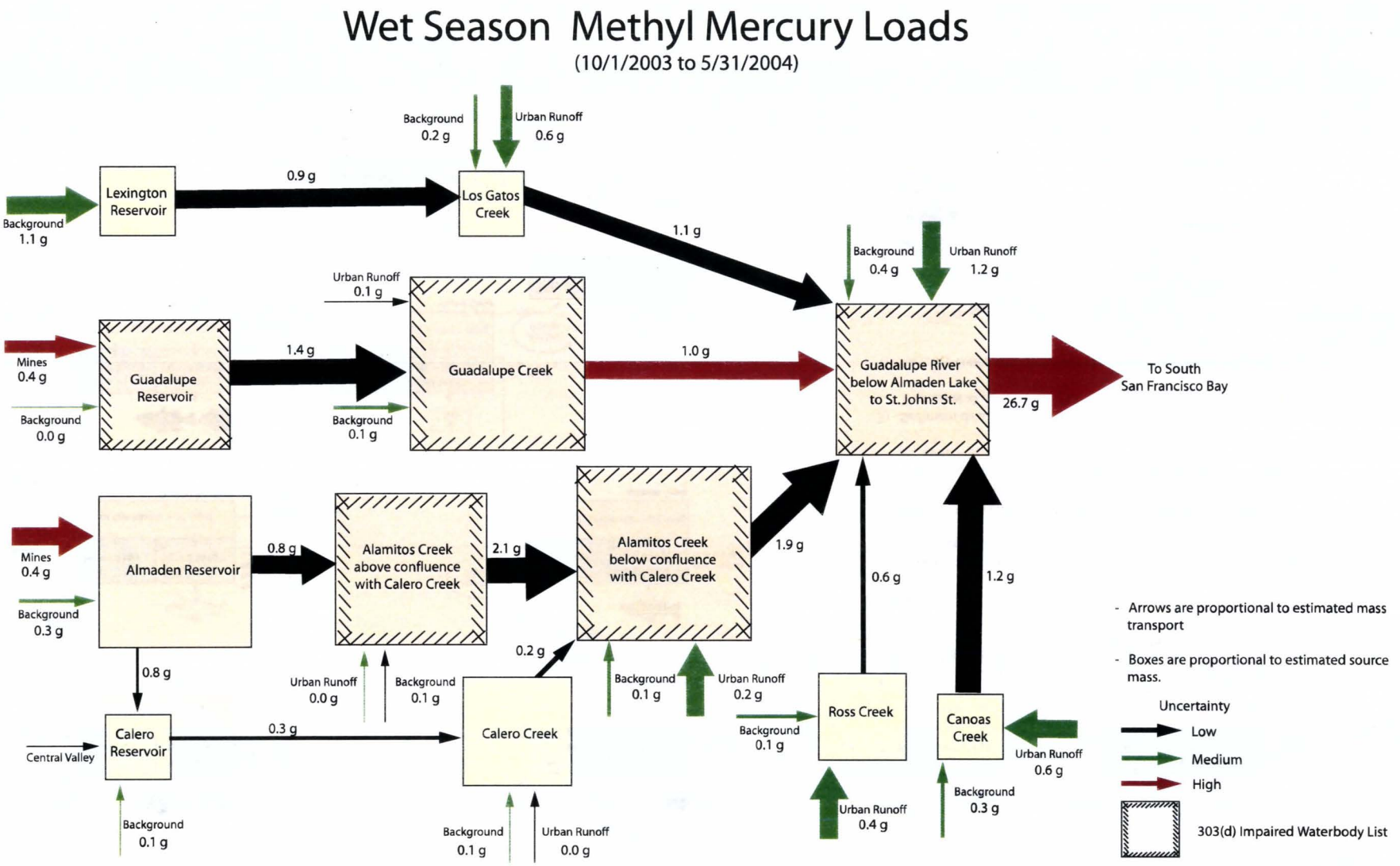


Figure 4: Graphical depiction of methyl mercury pathways through the Guadalupe River Watershed. All loads are in grams.

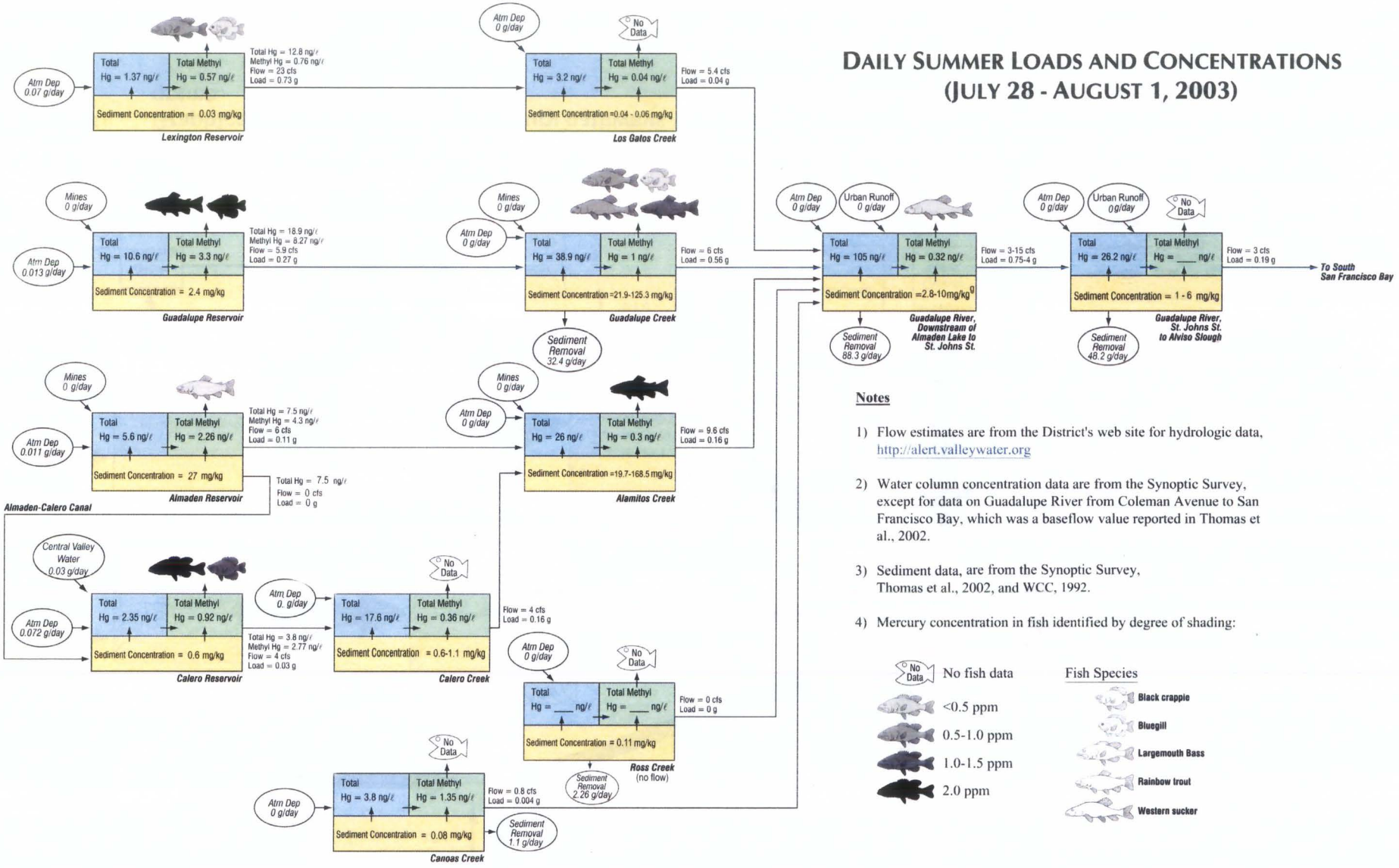


Figure 5: Graphical depiction of total and methyl mercury pathways through the Guadalupe River Watershed in the dry season. All loads are in grams.

- Sampling Element 5 provided information regarding the mercury content of bank and bed sediments in Guadalupe River, Guadalupe Creek, and Alamitos Creek. The data show that mercury concentrations decrease with distance from the mining district, ranging from 40 mg/kg above the Alamitos Drop Structure to 0.3 mg/kg at Highway 237. The data show that Lake Almaden and the Alamitos Drop Structure are obstacles to the transport of bed load sediment from the most contaminated creeks to Guadalupe River. Control measure activities in this area will be a critical component of the TMDL Implementation Plan.

- Sampling element 6, conducted during the dry season of 2004, was made possible by collaboration between the District and EPA. The District had the necessary permits and staff resources to collect fish from the creeks below the reservoirs. EPA provided the equipment and staff (supplemented with District biologists) to collect fish from Lake Almaden and from Almaden, Calero, Guadalupe, and Lexington Reservoirs, and for laboratory analyses of the fish samples. District staff collected fish from Los Gatos, Alamitos, and Guadalupe Creeks, and from Guadalupe River.

Adult Largemouth Bass

Total mercury concentrations were measured in muscle tissue samples from adult largemouth bass collected from Lake Almaden and from four reservoirs in the watershed (Table 1).

Table 1
Summary of Adult Largemouth Bass Mercury Data

		Total Mercury Concentrations (mg/kg wet)				Total Length (cm)			
Water body	**Sample Size**	**Average**	**Min.**	**Max.**	**Coefficient of Variation**	**Average**	**Min.**	**Max.**	**Coefficient of Variation**
Guadalupe Reservoir	18	6.1	3.1	13	0.40	41.8	30.7	53.2	0.18
Almaden Reservoir	20	4.3	2.2	7.4	0.30	43.9	33.8	51.2	0.11
Lake Almaden	20	2.3	1.1	3.8	0.34	41.8	31.2	53.2	0.16
Calero Reservoir	20	1.1	0.8	1.6	0.16	36.7	29.7	47.7	0.12
Lexington Reservoir	11	0.6	0.4	1.0	0.27	40.8	35.8	50.2	0.12

While all of the samples exceeded the State and Federal criterion of 0.3 mg/kg (for human consumption of fish), there were distinct differences in the fish mercury concentrations between the water bodies sampled. The mercury concentrations in adult largemouth bass in the immediate vicinity of the mining district are some of the highest fish mercury levels found to date in California. The maximum mercury concentrations in adult largemouth bass at Guadalupe and Almaden Reservoirs and Lake Almaden ranged from 3.8 – 13 mg/kg. In comparison, the maximum mercury concentration in largemouth bass muscle tissue measured statewide in the Surface Water Ambient Monitoring Program between 1986 and 2001 was 3.5 mg/kg.

Comparison to Regional Data

The Surface Water Ambient Monitoring Program (SWAMP) Report for the San Francisco Bay Region prepared by the San Francisco Bay Regional Water Quality Control Board describes surveys of reservoirs in which edible fish were collected and their tissues analyzed to

determine the concentrations of contaminants, including mercury, which may affect human health. Mercury concentrations were measured in largemouth bass in nine reservoirs in Marin, Contra Costa, Alameda, and Santa Clara Counties (Table 2). The comparison shows that the concentrations of mercury in largemouth bass from Lexington Reservoir and Calero Reservoir, not directly affected by the mining district, are similar to mercury concentrations reported for adult largemouth bass at other locations throughout the San Francisco Bay region. The comparison also shows that the concentrations of mercury in largemouth bass from the water bodies in the vicinity of the mining district area of the Guadalupe Watershed (Almaden Reservoir, Guadalupe reservoir, Lake Almaden) are elevated above the concentrations in the other reservoirs sampled in the San Francisco Bay area.

Table 2
Water bodies Listed by Decreasing Mercury Concentrations (mg/kg wet wt)
Standardized For A 40 Cm Largemouth Bass

Highlighted and *italicized* reservoirs are from the 2004 SWAMP database.

Water body	Total Hg (mg/kg)
Guadalupe Reservoir	5.8
Almaden Reservoir	3.6
Lake Almaden	2.1
Stevens Creek Reservoir	*1.4*
Anderson Reservoir	*1.3*
Calero Reservoir	1.2
Soulajule Reservoir	*1.1*
Del Valle Reservoir	*0.9*
Nicasio Reservoir	*0.8*
Lexington Reservoir	0.6
Lake Chabot	*0.6*
Lafayette Reservoir	*0.4*

- Sampling element 7, conducted during the dry season of 2004, was a focused study to evaluate the production of methyl mercury in Almaden and Guadalupe Reservoirs over the dry season. Methyl mercury is the chemical form of mercury most directly linked to uptake by biota. An understanding of methylation processes in reservoirs is needed to develop the linkage between mercury in the water column and mercury in fish. Elevated methyl mercury concentrations were measured in the hypolimnion and epilimnion of the reservoirs in the Synoptic Survey, but the zone of production of the methyl mercury is not known.

Data on total and methyl mercury collected during the dry season, 6 times over a fourteen-week period, demonstrated clearly the gradual buildup of methyl mercury in Almaden and Guadalupe Reservoirs. Much of the methyl mercury generated in the reservoirs was produced in the hypolimnion, which is where the withdrawals for downstream supply take place. The most significant production of methyl mercury occurred when the hypolimnion was depleted of oxygen (dissolved oxygen concentrations less than 1 mg/l, Figure 6).

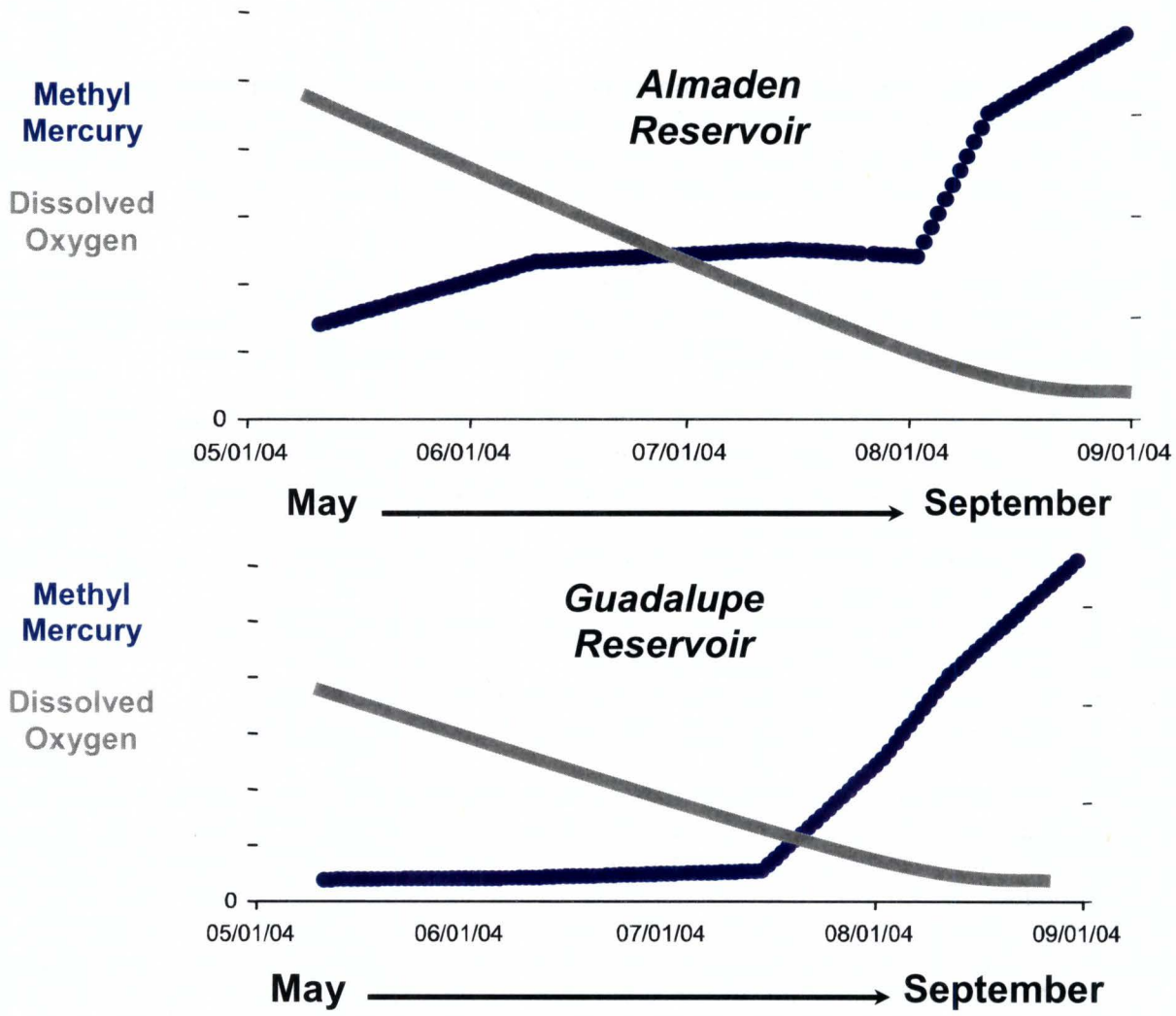


Figure 6: Methyl Mercury Production and Dissolved Oxygen Depletion

Project Summary

This project has produced a comprehensive set of data and data interpretations for use in development of a science-based TMDL for mercury in the Guadalupe River Watershed. In addition to providing technical information about numeric targets for the TMDL, the study has provided insight into implementation activities that will meet the targets effectively and efficiently.

The TMDL will contain numeric targets for mercury in fish, mercury in water and sediment, and methyl mercury in water that are protective of humans and wildlife exposed to mercury via consumption of fish. This will result in load reduction requirements as follows:

- total mercury loads to the reservoirs from tributaries draining the mining district;
- total and methyl mercury loads from the reservoirs to downstream creeks;
- total mercury loads to downstream creeks from tributaries draining the mining district and from urban runoff;
- total mercury loads to Lake Almaden and to the Alamitos Drop Structure from in-stream bed and bank erosion;
- total and methyl mercury loads from Lake Almaden and the Alamitos Drop Structure to the main stem of the Guadalupe River;
- total mercury loads to Guadalupe River from urban runoff; and,
- total and methyl mercury loads from Guadalupe River to the Bay.

The data indicate that significant mercury sources remain in the mining district, and mercury is transported primarily during storm events in drainages from the mining areas, including Randol Creek, Golf Creek, McAbee Creek, and Deep Gulch to creeks below the reservoirs, and Jacques Gulch and Los Capitancillos Creek to Almaden Reservoir and Guadalupe Reservoir, respectively. Sources of mercury are sediments eroding into the drainage and transported by flows, as well as erosion of the drainage banks and beds. The TMDL will establish load allocations for these drainages. The load allocations may be based on sediment concentration, suspended sediment concentration, water column concentration, or a combination of these. Some of the methods for achieving load reductions will be creek restoration, comprising sediment removal and erosion control within the District's ownership and easement areas.

Total mercury load allocations will also appear in the TMDL for Alamitos Creek, Guadalupe Creek, and Guadalupe River. These allocations may also be based on sediment concentration, suspended sediment concentration, water column concentration, or a combination of these. Again, some of the methods for achieving load reductions will be creek restoration, comprising sediment removal and erosion control within the District's ownership and easement areas.

In addition to total mercury, the TMDL process recognizes the importance of methyl mercury and the need to reduce its production at the same time that total mercury loads are being reduced. The TMDL will require load reductions of total and methyl mercury for the water bodies of the Guadalupe River watershed. However, reduction of total mercury exiting these water bodies is wholly dependent on reducing the sources of mercury entering these water bodies. Until the inputs are controlled, management of the water bodies to minimize the production of methyl mercury may be the only feasible choice. The District's best choice is methylation control coupled with stream restoration where waste is present on District lands, but this must be coupled with erosion control of mine waste inputs from the upstream lands of others, especially the New Almaden and Guadalupe mines.

The Implementation Plan of the TMDL will prescribe a control program that satisfies the load allocations within the watershed and the load allocation from Guadalupe River to the Bay, and the major areas where actions will be needed are depicted in Appendix A. Control programs for mercury have emphasized a combination of decreasing/eliminating mercury loads, natural/intentional burial of contaminated sediment, and reducing methyl mercury production. From the perspective of the Regional Board, responsibility for meeting load allocations will rest with current property owners, and will be enforced by the Regional Board under their existing authorities derived from the Porter-Cologne Water Quality Act and the Clean Water Act, enforced through the Basin Plan and permitting authority.

Decreasing or eliminating loads is a critical first measure, as it begins to reduce sediment mercury levels and the stock of new mercury to be methylated, and is usually the early emphasis of control programs. Dredging and removal or capping of contaminated sediment is employed less often than natural burial, primarily because of cost. Natural burial is problematic, due to the unpredictable behavior of sediments in active systems. Controlling methyl mercury production is a new frontier in restoration, since the factors involved are only now beginning to be well understood. However, it may be the best choice in certain situations, where other methods would be too environmentally destructive.

The District is in a unique position with respect to the TMDL. While not responsible for the initial and continuing release of mercury to the water bodies from the original source area, the District may be responsible for addressing mercury as a result of its land ownership, constructed facilities, and jurisdictional responsibilities. Fortunately, the District incorporated into a special tax approved by the electorate funds earmarked for addressing mercury issues, and, more importantly, most of the control measures that will be needed are essentially extensions of existing projects and programs the District already implements.

RECOMMENDED DISTRICT TMDL IMPLEMENTATION STRATEGY

The District's strategy to address mercury in the watershed is comprehensive and flexible, in that the entire watershed is being continuously assessed, and resources are applied where they are needed most. For convenience, the strategy is categorized according to major portions of the watershed (Figure 7).

Main Stem Guadalupe River

The main stem of the Guadalupe River is defined as extending from the downstream end of the Alamitos Drop Structure to the Bay. The emphasis in this portion of the watershed is reducing mercury loads to the Bay. Mercury sources under District control are bed and bank erosion. The study indicates that total mercury loading from this portion of the river is primarily due to in-stream processes. Methyl mercury production does not seem to be a major concern in this portion of the watershed, based on the fish tissue data and the water quality data.

The District's strategy in this portion of the watershed is to rely on its past and continuing routine maintenance program, that includes sediment removal and erosion control projects, and on its major flood protection projects, known as the Upper, Lower, and Downtown Guadalupe River Flood Protection Projects. The Lower project construction (from the I-880 bridge north to the Union Pacific Railroad bridge in Alviso), completed in 2004, is estimated to have removed over 400 kg of mercury from the Guadalupe River. The construction of the bypass in the Downtown project (from Grant Street north to Hedding Street) will result, by design, in a 20% reduction of sediment load (and, mercury load associated with that sediment) to the Bay. These accomplishments, plus continued maintenance of the Lower project to remove accumulated sediment is anticipated to achieve the average annual load reduction of mercury to the Bay specified in the Bay TMDL, at least for the initial 10-year period. Additional potential control measures that will be evaluated include periodic removal of sediment from the bypass, and the use of Pond A8 to capture sediment transported under flood flow conditions.

Incorporating mercury reduction measures into the Upper project (from Highway 280 north to the Southern Pacific Railroad crossing downstream of the Willow Street Bridge) and following completion of its construction (currently estimated at 2020) will further reduce the sediment and mercury load to the Bay. The current project design includes a bypass similar to the Downtown project. If this becomes part of the final design, periodic removal of sediment from the bypass will be evaluated as an additional means of reducing loading of mercury to the Bay. The maintenance program for the main stem of the River will be modified to prioritize erosion control projects using an additional criterion of mercury content. The annual identification of sites will include an assessment of mercury content. The existing criteria for prioritizing projects are protection of property and restoration of flood carrying capacity. Adding this criterion will inform the decision of which projects to undertake in a given year, all other criteria being equal.

Guadalupe Creek

The District completed the Guadalupe Creek Restoration Project in 2001. This project resulted in the restoration and revegetation of nearly 7000 linear feet of the creek between Almaden Expressway and Camden Avenue. Nearly 36,000 cubic yards of material containing over 400 kg of mercury was removed during construction. However, sediment production in this watershed continues to deposit sediment at the mouth of this creek. In 2002, 720 cubic yards containing 18 kg of mercury was removed, and in 2004, 500 cubic yards containing 13

kg of mercury was removed. Until upstream sources (primarily under private ownership) are identified and addressed, the District will continue to conduct this periodic removal of sediment. Portions of the upper reaches of Guadalupe Creek flow thorough areas where mine spoils (untreated waste soil and rock with elevated mercury concentrations) are eroding. Sampling results illuminate that tributaries draining mining areas are a continuing significant source of mercury load in high-flow conditions. Loads could be reduced beneficially if the mine owners would undertake restoration actions similar to those completed by the District.

Alamitos Creek, Deep Gulch, Golf Creek, Randol Creek, McAbee Creek

The District has ownership and/or easement over Alamitos Creek from Lake Almaden to Harry Road (approximately four miles). Above Harry Road to Almaden Dam (approximately six miles), the creek is in private ownership and the District has no easements. Deep Gulch is wholly within Almaden Quicksilver County Park (Park). The District has ownership and/or easement of Randol Creek and McAbee from their confluence with Alamitos Creek to the boundary of the park. The District has easement over Golf Creek from its confluence with Alamitos Creek to Golden Oak Way. Between Golden Oak Way and the park boundary, Golf Creek was converted to a municipal storm drain owned and operated by the City of San Jose.

Significant and numerous deposits of mercury are present in Alamitos Creek. Mine waste and debris comprise the bed and banks of much of the creek, with deposition events evident as visible strata on undercut banks (Figure 8). In 2003 and 2004, using grant funding from EPA, the District removed nearly 170 kg of mercury by restoring flood capacity, restoring vegetation, and reducing erosion potential at two sites on Alamitos Creek; Figures 9 and 10 show one of the sites before and after project construction.

All of the creeks listed above have some portion of their watercourse flowing thorough areas where mine spoils (untreated waste soil and rock with elevated mercury concentrations) are eroding. Sampling results illuminate that tributaries draining mining areas are a continuing significant source of mercury load in high-flow conditions. Loads could be reduced beneficially if the mine owners would undertake restoration actions similar to those completed by the District.

The District strategy is to identify and implement similar restoration projects along Alamitos Creek as part of its routine maintenance program. Generally, the projects serve multiple objectives of property protection, improving flood carrying capacity, restoration, and mitigation. In addition, the District will work with the property owners and regulatory agencies to develop a strategy for conducting projects in the privately owned portion of the creek.

Randol Creek and McAbee Creek are highly urbanized waterways that have extensively armored banks and are largely void of riparian vegetation. The portions of the creeks under District ownership/easement primarily act as conduits for the transport of sediments generated by erosion in the upper parts of the creeks inside the park boundaries. Occasionally, the District removes sediment from these creeks, but most is transported into Alamitos Creek. In 2002, the District removed 80 cubic yards of sediment containing 0.2 kg of mercury from Randol Creek. The strategy for these creeks is to work with the County to identify and evaluate erosion control options for these creeks.

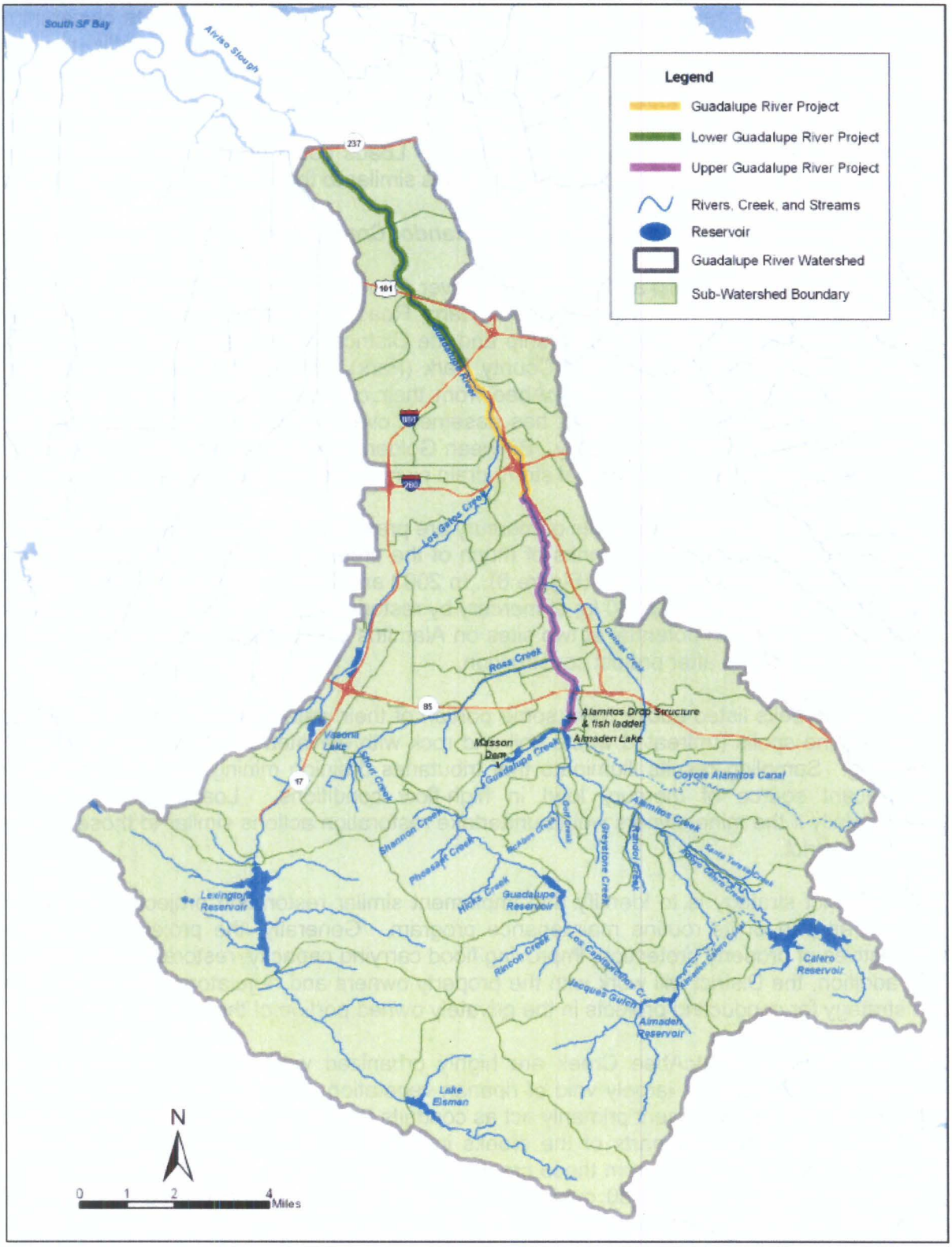


Figure 7 Guadalupe River Watershed and Guadalupe River Flood Protection Projects

Figure 8 Example of stratum of mine waste on undercut bank (Alamitos Creek)

Figure 9 Mercury removal project before construction (Alamitos Creek)

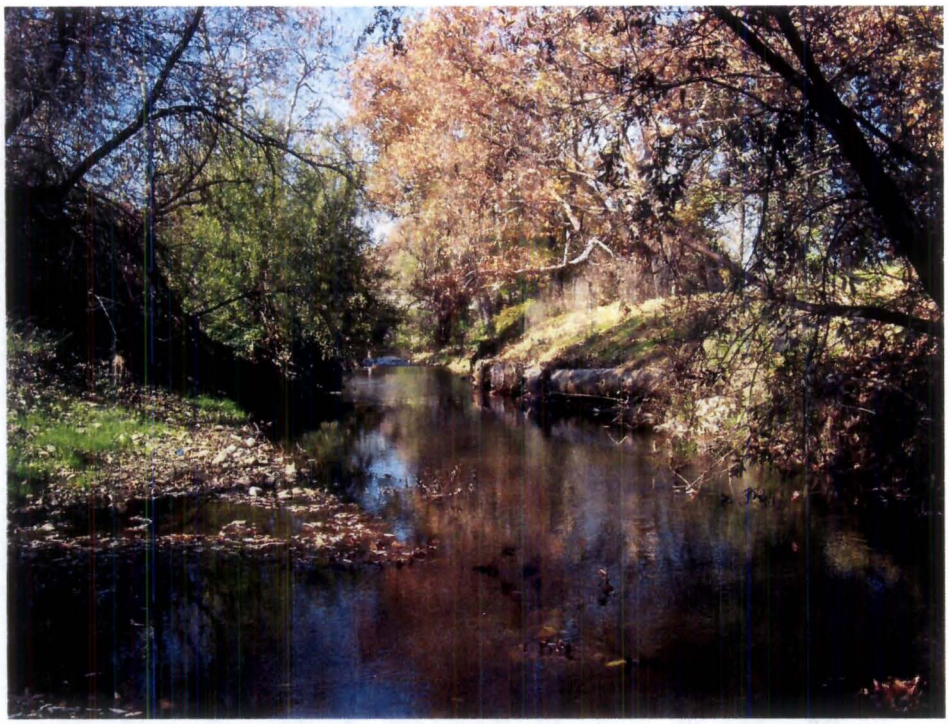


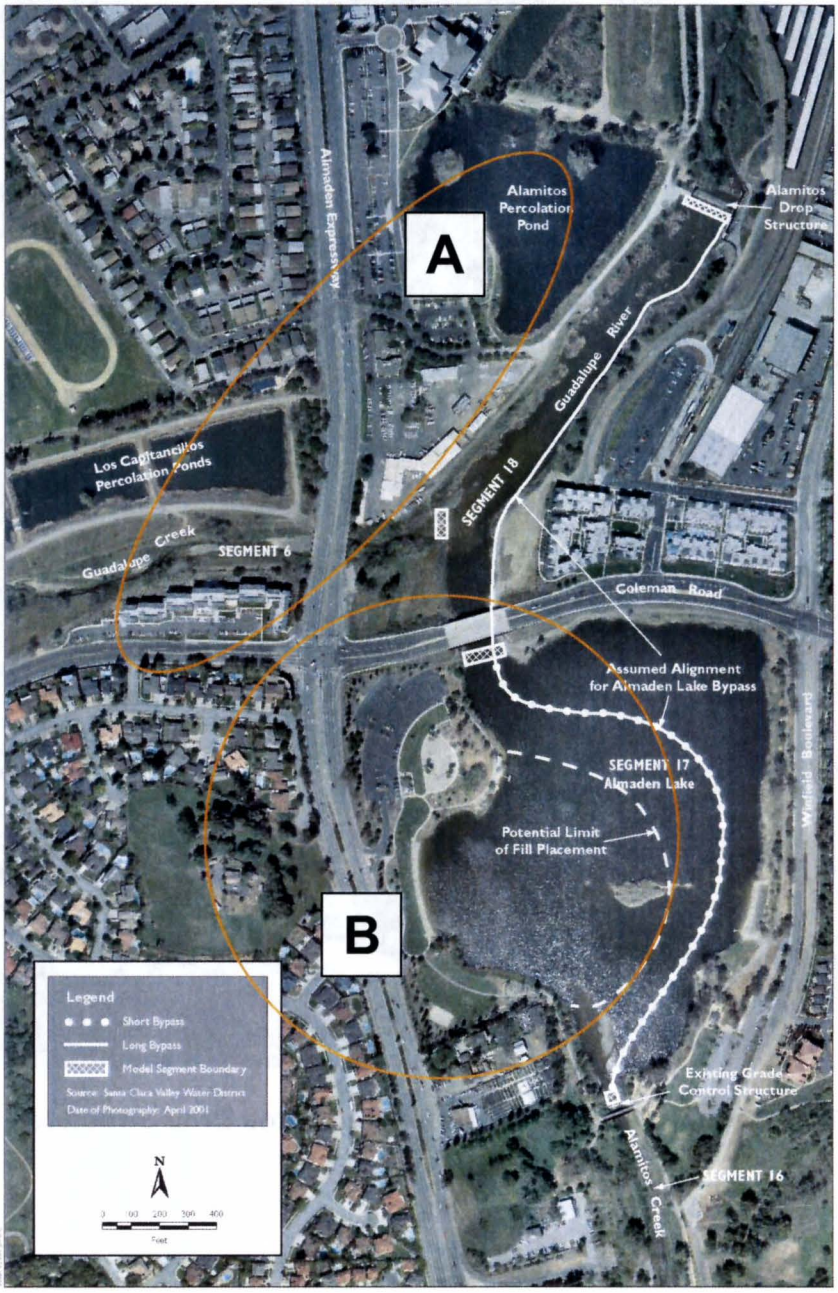
Figure 10 Mercury removal project after construction (Alamitos Creek)

Lake Almaden and Alamitos Drop Structure

These two facilities are owned and operated conjunctively by the District to provide recreational opportunities, groundwater recharge, and channel stabilization. The drop structure was installed to check channel erosion of the main stem of the Guadalupe River. The District annually installs a flashboard dam on the drop structure to enhance groundwater recharge.

The study indicates that Lake Almaden and the drop structure serve an important function of trapping the bed loads of mercury-containing sediment from Alamitos Creek and Guadalupe Creek, respectively (see Figures 11 through 14). The mercury content of this sediment is approximately 20 mg/kg, and the sediment represents a significant load of mercury that has been prevented from moving downstream to Guadalupe River and the Bay. The accumulation of sediment behind the drop structure is substantial, and the study indicates that this sediment is being mobilized during wet season flows and carried downstream. The study also indicates that the buildup of sediment in Lake Almaden, and possibly behind the drop structure, is creating conditions that promote methyl mercury production.

The District will evaluate the addition of sediment removal projects behind the drop structure and at the inlet to Lake Almaden into its stream maintenance program within the next few years. The frequency and duration of additional removal events is dependent on the implementation and effectiveness of control measures to reduce mercury sources upstream. In addition, control measures to reduce methyl mercury production in Lake Almaden and behind the drop structure will be evaluated and implemented. The most promising of these, aeration of Lake Almaden, will be pilot tested within the next few years. The long-term strategy is to develop and implement a restoration plan for this entire area to provide better habitat, improve fish passage, and enhance recreational opportunities.



Jones & Stokes

Figure 1
Confluence of Guadalupe Creek, Alamitos Creek, and Guadalupe River with the Assumed Alignment for the Almaden Lake Bypass

Figure 11 Recent Photograph of Alamitos Drop Structure (A) and Lake Almaden (B) Area

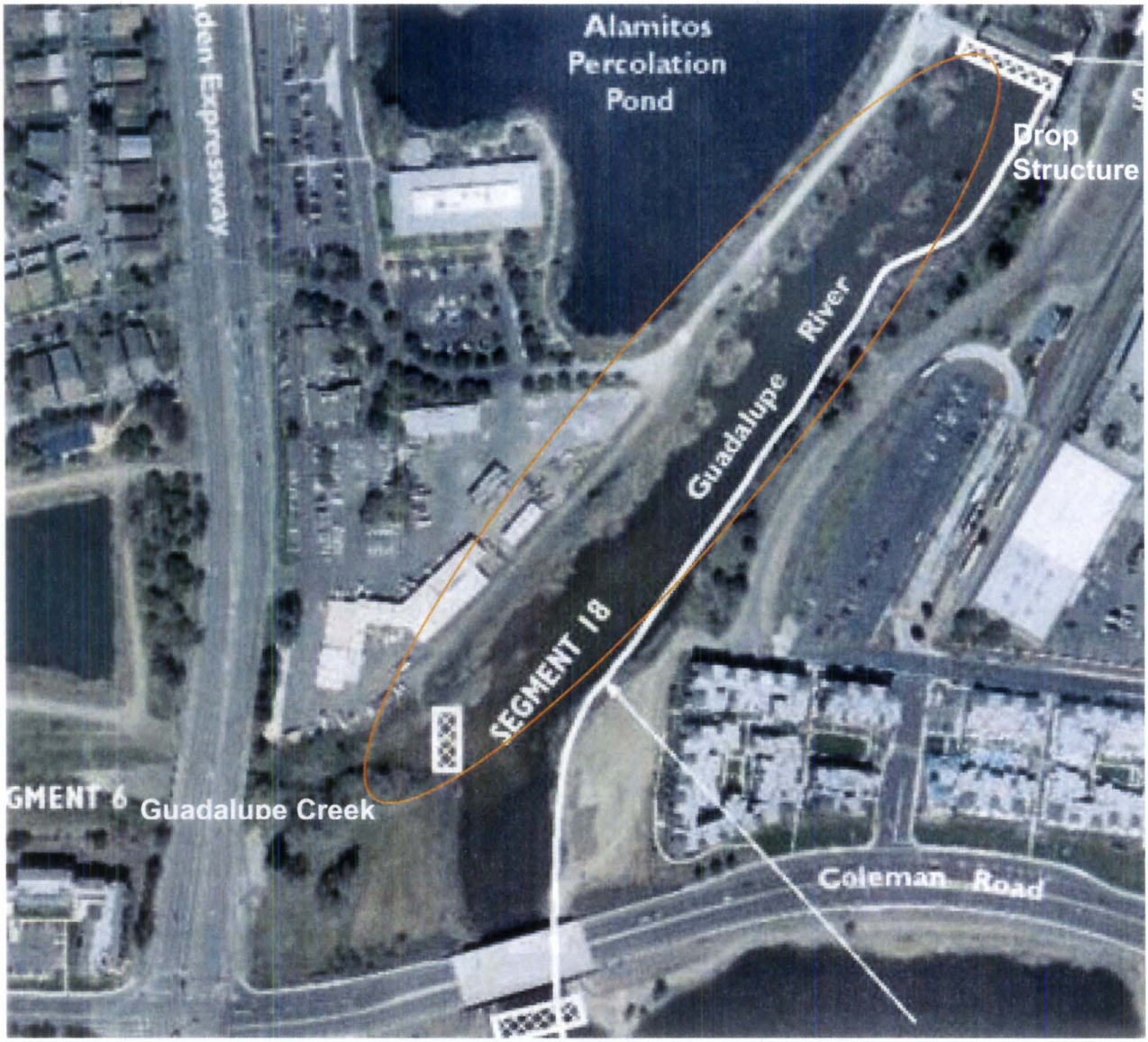


Figure 12 Sediment deposition behind Alamitos Drop Structure

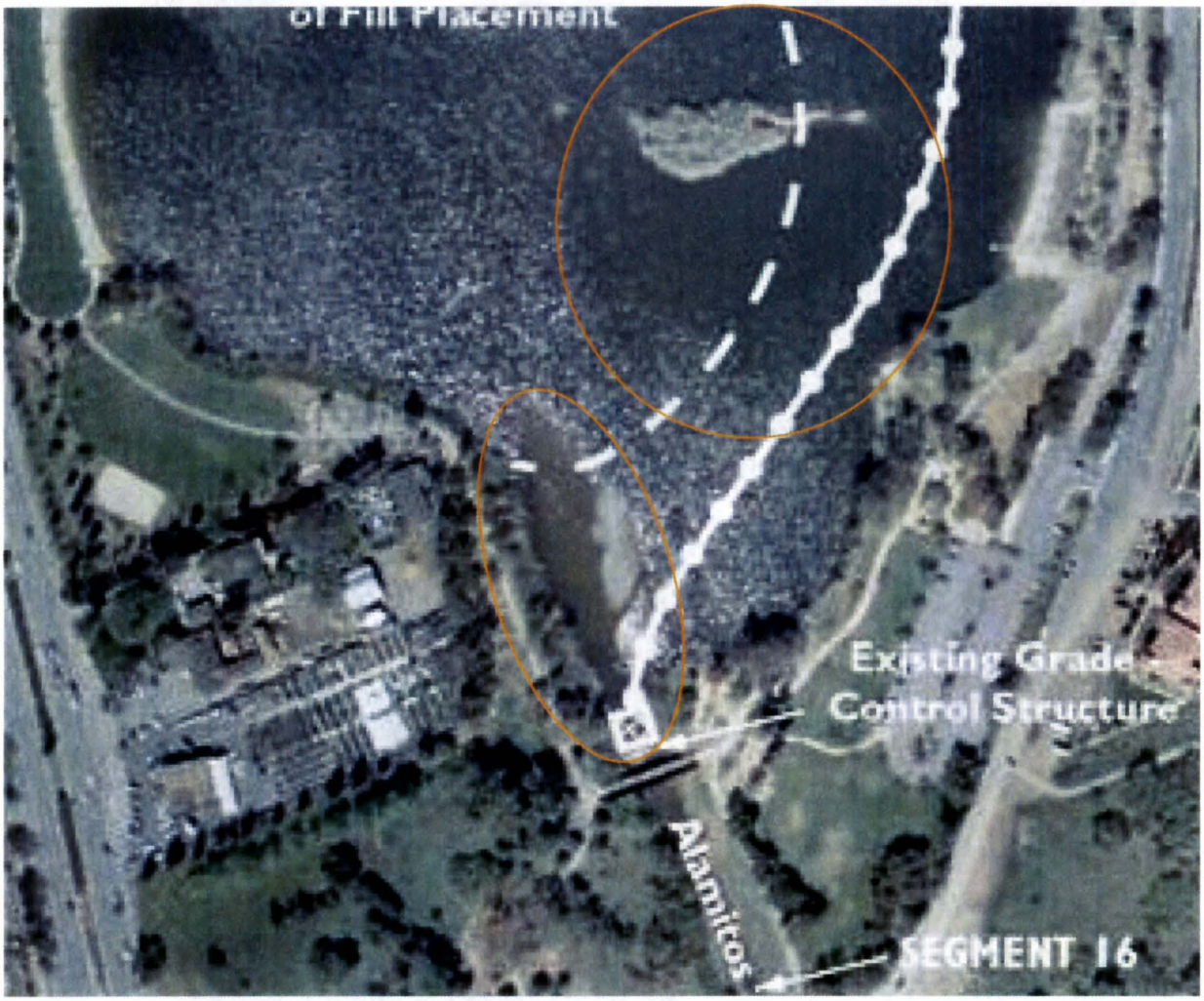


Figure 13 Sediment deposition areas in Lake Almaden

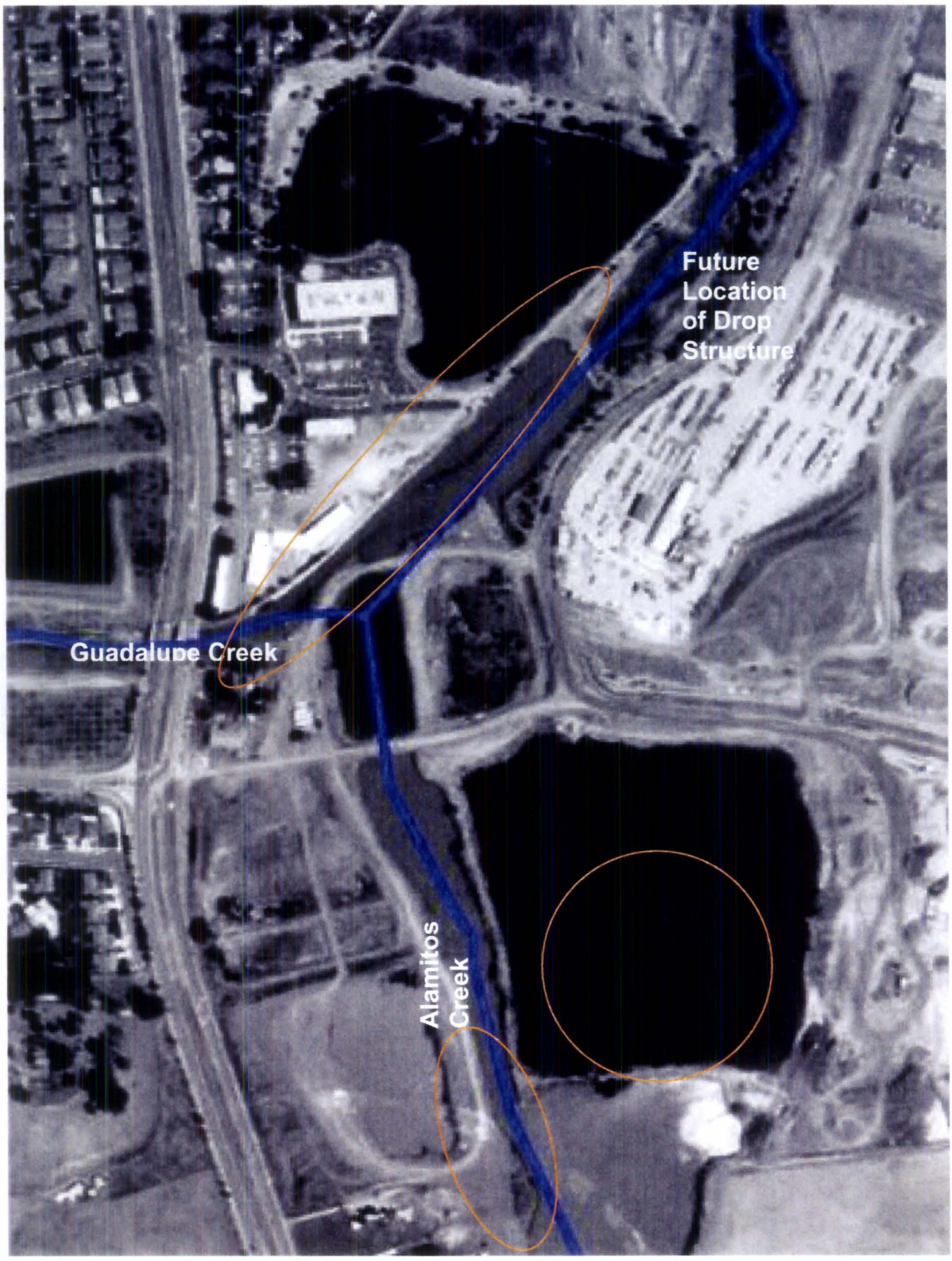


Figure 14 1976 Photograph of confluence of Alamitos and Guadalupe Creeks, showing the same areas outlined in Figures 19 and 20

Almaden and Guadalupe Reservoirs

Control measures for these two reservoirs include reduction of mercury entering the reservoirs and identifying and evaluating measures to reduce methyl mercury production in the reservoirs. The ultimate long-term solution for the reservoirs is to reduce the input of new mercury as much as possible as soon as possible, and allow natural burial to occur within the reservoirs. Management of the reservoirs to reduce the production of methyl mercury is essential to restoration of the beneficial uses in the shortest possible time. The District will also explore the potential of retiring one or both of these reservoirs as part of a multi-objective approach to restoration of the upper watershed of the Guadalupe River.

The study demonstrated that methyl mercury production in the reservoirs is strongly correlated with depletion of oxygen in the hypolimnion during the warm dry season. Addition of oxygen to the hypolimnion of reservoirs is a developing industry that has been successfully implemented in water bodies the size of holding ponds to reservoirs with capacities of hundreds of thousands of acre-feet. The benefits of aerating reservoirs extend beyond the potential for reducing methyl mercury production, such as improving water quality and habitat in the reservoir and downstream.

The District's strategy for the reservoirs includes:

- Implementation of a stream restoration project on Jacques Gulch to reduce the input of mining waste into Almaden Reservoir. Jacques Gulch is the only source of mining waste to Almaden Reservoir. This project is scheduled for completion in 2011.
- Working with the County to identify and evaluate erosion control options for mining waste sources into Guadalupe Reservoir.
- Conducting a feasibility study of aeration for these two reservoirs and pilot test aeration in one of the reservoirs by 2007. If successful, implement aeration in all three reservoirs by 2011.
- Conduct a reconnaissance level evaluation of the potential for retirement of one or both of these two reservoirs.

Calero Reservoir

Control measures for this reservoir includes reduction of mercury entering the reservoirs and identifying and evaluating measures to reduce methyl mercury production in the reservoirs.

The District's strategy for this reservoir includes:

- Identifying and evaluating erosion control options for mercury-containing sediment entering the Alamitos-Calero Canal that is used to transfer water from Almaden Reservoir to Calero Reservoir.
- Inclusion of this reservoir in the feasibility study of aeration mentioned above.

The recommended District strategy was developed to incorporate and integrate mercury issues into existing programs and projects to the maximum extent practicable. Mass removal of mercury is integrated into the existing stream maintenance program for those creeks over which the District has ownership/easement, and evaluating aeration of reservoirs is integrated into existing reservoir operations. Separate projects include evaluating aeration to reduce methyl mercury production in Lake Almaden and behind Alamitos Drop Structure, restoration of Jacques Gulch, and working with the County and private landowners on the creeks to evaluate erosion control options. This strategy addresses the Cleaner, Greener, Leaner goals of the District:

- Cleaner:
  - Improved water quality for fisheries in the reservoirs and downstream creeks
- Greener:
  - Restored and enhanced environment in the reservoirs and downstream creeks
  - Improved fish habitat and related food cycle and wildlife habitat in the reservoirs and downstream creeks
  - Improved recreational opportunities
- Leaner:
  - Utilization of existing projects and other proposed multi-objective projects and activities to simultaneously address stream stewardship, flood protection, and water supply interests
  - Proactive action to minimize regulatory administrative burden

APPENDIX A

Major Focus Areas for TMDL Implementation

Guadalupe Watershed

Pond A8:
Sediment Trapping

Lower Guadalupe Sediment Removal
-Capital Project (2003-04)
-Maintenance

SFEI Monitoring Station

Downtown Guadalupe Sediment Load Reduction
-Bypass (2003-04)
-Maintenance

Santa Clara County

Guadalupe Watershed (Central Zone)

Location

Downtown Guadalupe Sediment Load Reduction
-Capital Project (2020)
-Maintenance

Alamitos Drop Structure
- Sediment Trapping/Removal
- New Maintenance Program

Guadalupe Creek
-Stream Restoration (2001)
-Maintenance

Almaden Lake
- Sediment Trapping/Removal
- New Maintenance Program
- Stream Restoration (?)

Guadalupe Creek (private)
-Stream Restoration?
-Maintenance?

Alamitos Creek
-Maintenance
-Stream Restoration (?)

Guadalupe Reservoir
- Treatment (Oxygenation)?
- Operations?
- Dam Removal

Los Capitancillos Creek (SCCPR)
-Stream Restoration?

Jacques Gulch
-Stream Restoration (2009)

Almaden Reservoir
-Treatment (Oxygenation)?
-Outlet Works Project
-Operations?
-Dam Removal?

Alamitos Creek (private)
-Stream Restoration?
-Maintenance?

Calero Reservoir
-Treatment (Oxygenation)?
-Canal Project
-Operations?

Legend

- SCVWD Streamflow Station
- USGS Streamflow Station
- Canals
- Water Treatment Plant
- Pump Station
- Raw Water Turnout
- Levees
- Historical Mercury Mines

Instream Dams
- Historical Use/Permitted
- Historical Use/Retired Permit

Water Distribution Systems
- Raw Water Pipeline
- Treated Water Pipeline

Generalized Geology
- Basin Interior (Confined Zone)
- Bedrock Island
- Santa Clara County Uplands
- Unconfined Zone

Existing Project/Program

Project/Program Needed

1 0 1 Miles

Project/Program Needed on Property Owned by Others

Santa Clara Valley Water District
5750 ALMADEN EXPRESSWAY
SAN JOSE, CA 95118-3686